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Dimension of Hydrological Extremes and Its Consequences: An Overview

Dr. Zafar Tabrez & Prof. (Dr.) Nelia Lois Chauhan
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Published by: Global Center for Social Dynamic Research
zafartabrez1310@gmail.com
nelialois.chauhan@yahoo.in

Abstract

Hydrological extremes like floods and droughts are considered to be the most important among all the other hydrological events. These extreme hydrological events can be considered in the context of the three dimensions of security, viz. economic, social and environmental. The different studies disclose that there is an increasing occurrence of hydrological extremes at the global level. Droughts may be regarded as natural phenomena, the recurrence of which is certain. The frequency as well as intensity of drought has increased sharply as a consequence of climate change. Floods are the most widespread of all-natural disasters which can damage houses, industries and public property. Floods are mostly affected by precipitation and temperature patterns. Some of the important activities associated with flood protection and management are the setting up of various structural as well as non-structural measures. The present paper discusses extreme hydrological events in general and floods and droughts in particular. The important aspects of the floods and droughts have been highlighted by the researcher accumulated from various studies and sources. The paper also discusses the remedial measures and suggestions which are necessary to overcome the extremes of hydrological events.

Keywords: Hydrological, Floods, Climate, Frequency, Drought.

1. Introduction

Hydrological extremes occur with high magnitude and low frequency on the earth's surface. They occur due to closely connected forces from various aspects of geophysics, i.e., oceanographic, meteorological and seismological processes. They are complex in their water distribution both spatially and temporally, its impacts and phases. They develop often over the interfaces of marine water with freshwater, snowy solid and icy, atmospheric and ground waters (Cudennec et al. 2015). Kundzewicz et al. (2015) in their paper on "extreme

hydrological events and security" have stated that the extremes related to water can pose serious threats to societies' security, undermining welfare and human life. Droughts and floods are considered in the context of the three dimensions of security, namely social, environmental and economic. The effect of floods and droughts may create difficulty for local people by damaging their health, food, water and well-being. In many regions of the world, the rural communities face loss of life and property as a consequence of flooding, while in semi-arid and arid parts of the world, the situation of droughts exacerbate scarcity of water and also lead to decrease in fisheries, agricultural yields and loss of resources which are biological in nature.

The Intergovernmental Panel on Climate Change (IPCC) stated weather extremes as "an event that is seldom at a particular place and time of year". Different studies show that the occurrence of extreme hydrological events and their variability has been increasing at the global level. The increase in moisture-holding capacity in the atmosphere would likely increase the occurrence of heavy precipitation events. The different studies also reveal that there is a trend of increasing dry spells between rainfall events. Almost 800 million people in different areas of the world are residing in areas which are more vulnerable to floods and 70 million people are trapped in floods every year. The nations having the highest share which are exposed due to floods are Cambodia, whereas in Bangladesh flood occurs more frequently, in absolute as well as in relative terms (Kundzewicz et al. 2014). Predictions reveal that heavy rainfall will be getting more intense and frequent, negatively affecting the risk involved due to floods generated by rain (urban and flash flooding), soil erosion and landslides. (Seneviratne et al. 2012). New appraisal- 'The Winter Floods in the UK of 2015-2016' funded by the Natural Environment Research Council, brought both meteorological data and river flow together in an assessment of the major events resulting in devastating floods in Scotland, Northern Ireland, Wales and northern England.

Hydrological extremes like floods and droughts vary temporally and spatially in nature. Mostly rivers tend to flood every one to five years. Discharging river water during these events is ten times the mean annual flow and hundreds to thousands of times more than the lowest water flow. Most of the seasonal rivers dried up after a few years and there are increasing cases of water scarcity. Various studies disclose that global flood damage has become more frequent and has tripled since the 1980s. The losses are higher in developed parts of the world, whereas the fatality rates and economic losses are much higher in developing countries. On the contrary, a situation like drought has become more intense, longer and widespread in many areas of the world as a consequence of a decrease in precipitation and subsequent warming of the land area

that enhances evapotranspiration and drying. Security context of hydrological extremes are challenging issues. Processes that are natural in nature are the different sources of the risks that are inseparable from human interventions (Kundzewicz et al. 2015). Yang et al. (2015) in their paper discussed that global warming act as a catalyst in hydrological cycle processes that causes the redistribution of different water resources both temporally as well as spatially. Luca et al. (2020) in their paper on "Concurrent wet and dry hydrological extremes at the global scale" has discussed that "extreme hydrological events" doesn't merely imply observed drought and flooding unless mentioned explicitly. Disasters related to water, i.e., surplus or water deficit, droughts and floods, are more intense and disastrous as far as suffering, economic damage and deaths are concerned. In spite of the achievements in scientific knowledge and development of various techniques, humans still are more vulnerable to hydrological extremes. The losses accelerated as a consequence of growth of valuable infrastructure, growth in the density of population and reduction in the buffering capacities (urbanization, draining wetlands and deforestation). One can easily mention these events of recent times as floods in Bangladesh and in Sahel as extended drought. (Kundzewicz et al. 1993).

Most of the occurrences of annual flood is experienced in spring when soil is having more moisture content, and in some areas, flooding is also affected by frozen ground (Small et al. 2006). The human and economic losses from hydrological extremes have encouraged the communities to be alert to the predictability and causes of these extremes (Trenberth, 2011). In recent times, a study of patterns of rainfall and its characteristics has attracted attention of everybody, owing to conditions of weather extremes and its related changes in climate that have observed (Nandargia et al. 2016). The impact of change in climate plays them out through water system concerning hydrological extremes (Beniston et al. 2007). What defines extreme occurrences varies across different disciplines and studies, wherein it is interchanged usually with their effect (McPhillips et al. 2018). Floods that are associated with severe rainfall will likely become more frequent (Hirabayashi et al. 2017).

Hydrological extremes play an indispensable part in the ecosystems and are the main concern for society, significantly affecting the health of ecosystem, economy, human health and services. These extremes are mostly important evidence of change in climate for the people in different regions. It is therefore essential to acquire knowledge for the management of water prudently, sustainably and fairly to overcome shortage of water. A proper policy for reducing disaster risk and efficient response in an emergency can reduce the material damage and human casualties

to a great extent. Information about warnings, forecasts, hydrological data and related information about low and high ice and water conditions, must be promptly disseminated to all the persons involved in the management of water resources and the media, to reduce negative consequences of extreme events (Stankovic et al. 2019). Various approaches are used to overcome drought and flood control management and planning incorporating interactive and active participation of users, or parties affected, in the process of decision making (Johnson, 1990). Understanding droughts and floods, their characteristics, regularities and mechanisms are of utmost importance for the assessment of water, its allocation, management and design of water resource systems (Kundzewicz et al. 1993).

2. Droughts

The recurrence of droughts, which is a natural phenomenon, is certain. In spite of the advancement in technology, the impact of droughts has increasingly become serious as a consequence of the increase in water demand. Long-term and short-term effective strategic plans and remedial measures are necessary for the successful defense against the occurrences of future droughts. Technological advancements are required to execute the plans properly, to make predictions and monitor capabilities at the stage of their implementation. Adequate knowledge is required for the proper planning and timely reactions to drought, its characteristics, socio-economic stresses, and the results of the different mitigative policy and planning alternatives (McKay et al. 1989).

Droughts can be regarded as a catastrophe for the natural environment and have attracted researchers, academicians and environmental planners from various disciplines (Khan et al. 2018). The phenomenon of drought affects large areas and is responsible for the cause of severe economic losses and damage to human well-being. (Wilhite, 2000). In the field of plant and agricultural sciences, there are variations in the operational definitions, mainly owing to the time scales of different events that have been taken into consideration. (Passioura, 2007). As a consequence of change in climate, the intensity and frequency of extreme events like drought are rising at an exorbitant rate, which is having severe consequences on the fragile ecosystem and human society (Min et al. 2011). Since the 1970s, the dry regions in the world have increased by about 1.5 times (Dai et al. 2004). The classification of four types of droughts is based upon water deficiency (Vasiliades et al. 2017). Meteorological drought- having less or no rain (or does not have adequate rainfall, i.e., rainfall below normal). Hydrological drought- a duration of low stages and low flows of surface waters i.e., lakes, rivers and low levels of

groundwater. Agricultural drought- occurs when soil is having low moisture content for supporting crops. Socio-economic drought- When human activities are linked with the elements of agricultural, hydrological and meteorological drought.

Proper drought assessment plays an important role in the management of water resources (Mishra, 2010). Relevant future drought related information is of utmost importance for drought preparedness and long-term regional water plan. (Yuan et al. 2017). The evaluation and analysis of the conditions of drought is crucial for risk management and drought mitigation. Hydrological drought events can be explained in various drought characteristics like duration, magnitude, occurrence period, minimum flow and drought frequency. Various methods and techniques have been designed to get this characteristic, which implies contrast in defining drought. This is due to the fact that the occurrence of drought is a worldwide phenomenon and impacts streams and rivers having different types of hydrological systems (Hasan et al. 2019). To deal with the negative impact and reduction of drought, proper planning is a pre-requisite condition for the mitigation and management of drought. The key point of coping with droughts is drought preparedness. There could be various steps that are indispensable for the reduction, mitigation and management of drought. The steps in the above-mentioned process are: Setting up task force for drought, emphasizing the objectives and purpose of the preparedness plan, Stakeholder's participation to resolve conflicts, identifying research needs and filling institutional gaps, building public awareness at the local level, teach people about causes and consequences of drought and evaluate, assess and revise drought preparedness plans.

3. Floods

Floods can be considered as widespread among all the other natural disasters. Floods can cause hefty damage to industries, public property and houses, which may lead to huge losses of human lives and property. However, it is impossible to avoid the flood related disasters completely; different non-structural and structural measures can be adopted to minimize the damage from floods. Bates et al. (2008) has found that floods are mostly affected by different climatic system, mostly due to rainfall (duration, amount, timing, intensity, phase—snow or rain), but patterns of temperature also (responsible for these phenomena as ice melt and snow, ice jam formations and soil freezing). Close to the level of sea, flooding of rivers can be concurrent with storm surges or events like severe tide (Brakenridge et al. 2013). Countries like India, China and Pakistan experienced heavy flooding in 2010 summer, October-December 2010 in Columbia and during the austral summer of 2010/11

in Australia. There were around 2000 fatalities in Pakistan due to monsoonal flooding of 2010 (Syvitski and Brakenridge 2013). The situation of floods can occur due to heavy rainfall followed by the inability of rivers to hold back the water along their banks (NIDM, 2015). Damage associated with floods is not only the function related to speed, depth and persistence of the river water but also of the suspended and dissolved load of the flood waters (Kundzewicz et al. 2012).

In 2011, floods of severe nature occurred in Asia, Africa and the Americas; with casualties in every flooding exceeds 50 (over 1000 in Colombia and Philippines) and huge material damage (Kundzewicz et al. 2012). The assets and population in some countries are concentrated in areas of flood prone. The countries having largest portion of population exposed to floods are found in Bangladesh, Vietnam and Cambodia (Peduzzi et al. 2009). There are different types of floods which can occur in any region depending upon the area it affects, the source of occurrence and the losses it creates in a region: Flash flood- Due to excessive rainfall the surface runoff occurs and leads to a rise in the height of stream. River flooding- occurs due to heavy rainfall for over prolonged period and subsequently cause huge damage to nearby assets. Groundwater flood- when rainfall occurs for an extended period, there is an increase in the level of water above the surface and results in flooding. Coastal floods occurred due to the blowing of strong winds and storms that continuously move towards the coast during high tide. Drain and Sewer Flooding- it is caused due to blockage within the drainage system. Sewer flooding and drains may be internal (within a building) or external.

There can be various activities that are required for the management of floods, some of the important activities associated with flood management are mapping the flood-prone area, there should be no major construction in the flood prone areas and flood resilient strong engineered structures should be encouraged to construct. Moreover, the construction of buildings should be in an elevated area and if required should be built on stilts. Rehabilitation of the community to higher and safer areas before the occurrence of floods can avoid danger to property and life. Early action in providing the services and relief like water supply, food and medicine helps in early recovery and less damage whenever a disaster occurs (Tripathi, 2015).

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4. Conclusion

Hydrological extremes such as droughts and floods, owing to their negative impact on the lives of millions of people around the world, have become a matter of great concern for society. In spite of the development in the various aspects of science and technology, the communities still face the events of hydrological

extremes. Extreme hydrological events vary spatially and temporally in nature and have become most disastrous so far as economic losses, suffering and deaths are concerned. It has been revealed from various studies that the damage due to global floods has been much higher in developing countries. The situation of drought is becoming more severe, widespread and of much longer duration in many parts of the world and consequently warming the land area that enhances evapotranspiration and drying. Adjustments of humans to droughts and floods have resulted in making planning and preparedness for defensive purposes. With structural measures, protection can be achieved. Channel regulations, Levees and dikes are some of the examples of structural measures against floods; on the contrary desalination plants and water transfers are the structural measures against drought. However, due to the high cost required in structural measures, it is therefore essential to use non-structural methods like flood insurance, flood forecasting, water conservation, flood proofing and water demand management to eradicate droughts (Kundzewicz et al. 1993).

The impact of drought has become more serious and challenging due to the increase in water demands. The occurrence of drought has increased considerably as a result of climate change. For efficiently managing drought, it is necessary to analyze the drought conditions. There can be various methods that are required to overcome the negative impact and management of drought. Among the various steps, some of the important ones are setting up a drought task force, creating awareness among the people in a locality or region experiencing drought, Stakeholder participation, Teaching people about drought and evaluating, assessing and revising drought preparedness plans. Flooding has always been a part of human history. They destroy buildings and houses and remove fertile soil from farming land. Floods are the most widespread of all natural disasters. There could be various types of floods which can occur in any region depending upon the source and the losses it creates in a region or locality. For proper planning and flood management, reliable, accurate and timely information is required.

The application of telecommunication, science and technology and media can be helpful in reducing devastation. Setting up an alarm system at the riverbank can alert nearby communities to increase the levels of water and can also be helpful to reduce the damage. Rehabilitation of people in safer areas before the flood occurs can help in reducing the losses of life. Instant supply of medicine, water, food, goods and services helps in early recovery and less damage after disaster (Tripathi, 2015). There can be various structural measures like embankments, sea walls, flood walls, dams and reservoirs, and Diversion of flood waters, which are applied for protection of

flood. There are various non-structural measures for protection from the floods which are of utmost importance like floodplain zoning, warning and flood forecasting, flood insurance and flood proofing.

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